GLOVEBOX HEAT TEST

by

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Abstract: An existing argon atmosphere glovebox enclosure was to be refurbished for contaminated operations with a large, high temperature induction furnace. Thermal modeling indicated that glovebox temperatures would be high but acceptable without active cooling, but there were significant concerns that the analysis was inadequate and active cooling would be required. In particular, radiant heating of the glovebox walls by the furnace and pressure control system performance were concerns the thermal model had not addressed. Consequently, a thermal load test with a simulated furnace was designed to answer these questions. The purpose of the test was to determine if active cooling would be required to maintain containment integrity and, if not required, would it still be desirable for improved operations?

Background

As part of the Spent Fuel Treatment Demonstration Program for the Department of Energy, Argonne developed and operated a large (7'x 9'x16') argon atmosphere glovebox in 1997 (see *Figure 1*). The purpose was development and qualification of hot-cell equipment used in the preparation of a ceramic waste form for high-level nuclear waste. The glovebox allowed testing of equipment under conditions simulating our hot-cell environment. While the work demanded tight atmosphere purity control, there were

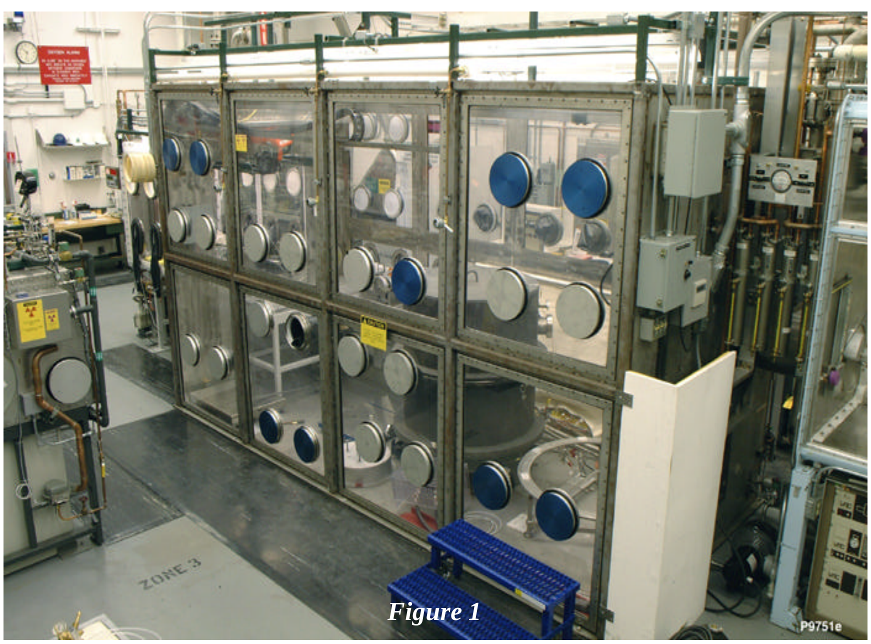

Figure 1

no radioactive materials involved and the enclosure could be run at positive pressure. After the ceramic waste equipment was transferred in cell, the enclosure was chosen to house a developmental furnace for high-level waste in the form of metal ingots. This furnace was to be operated in the glovebox and would require work with uranium and uranium chloride. The glovebox would therefore need to be operated at negative pressures to preclude release of any radioactive materials and upgraded for maintenance and operation under radiological controls.

The development furnace had been designed, built and operated in air. Its operational characteristics, shell temperatures and power input were known, so a model was created to estimate what glovebox atmosphere temperature would be required to transfer the 20 kW estimated heat output from the furnace shell to the room atmosphere outside the glovebox. This answer was 50° C, which was well within design limits for the glovebox containment boundary materials. However, the effects of radiant heating from the furnace to the glovebox walls and non-uniformity in glovebox atmosphere temperature were not accounted for in the model. Further modeling based on a more detailed furnace thermal model was performed and indicated the potential for slightly higher temperatures, but the uncertainties were still high. It was therefore decided to simulate furnace run conditions early in the enclosure modification program such that the potential addition of active cooling for either safety or improved operation could be assessed.

<u>Test Design</u>

The metal waste furnace (shown in *Figure 2*) is an induction furnace designed to heat 60 kg charges of steel alloys to 1800°C under vacuum conditions. It is powered by a 3kHz power supply rated at 50kW. This power is used for heat up. Because of the heat capacity of the furnace charge, internal structures and insulation, the heat transferred to the glovebox depends on the furnace shell temperatures, which increases slowly even with the 50kW heat up power. The maximum heat load is determined by steady state power required to hold maximum furnace temperature and is in the range of 15kW to 20kW for anticipated operations with this furnace. The metal waste furnace will be positioned 4.5 feet from the west end wall and centered side-to-side.

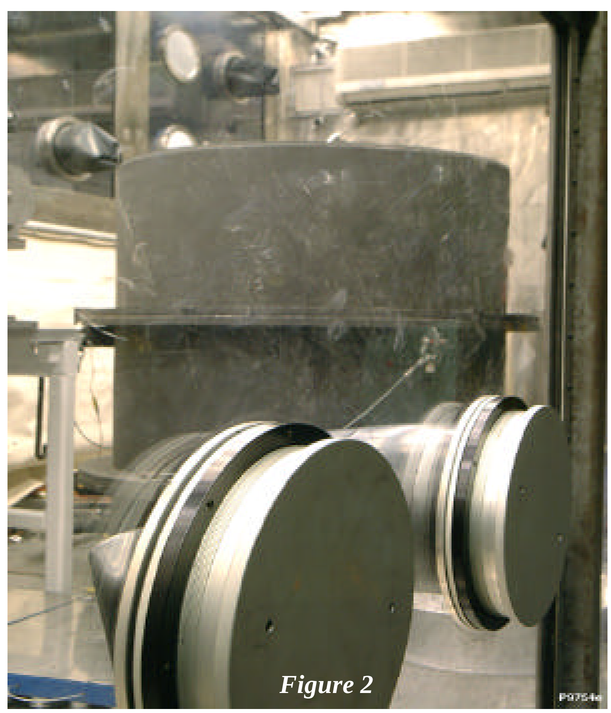

Figure 2

The simulated furnace for the heat test needed to provide at least 20kW with realistic shell temperatures, surface areas and surface emissivities. The last elements are important because the shell temperatures approach 300°C and the polycarbonate glovebox side windows are only 18 inches away. They strongly absorb infrared energy, and casual experiments with polycarbonate panels during air operation of the furnace showed significant bowing. It is also desirable for the simulated furnace to have a faster response to power level changes in order to assure that the pressure control system has some capacity margin beyond that anticipated for the furnace. Rather than risk damage to the actual furnace, a simulated furnace was designed and constructed. The final design is shown in *Figures 3a* and *3b*.

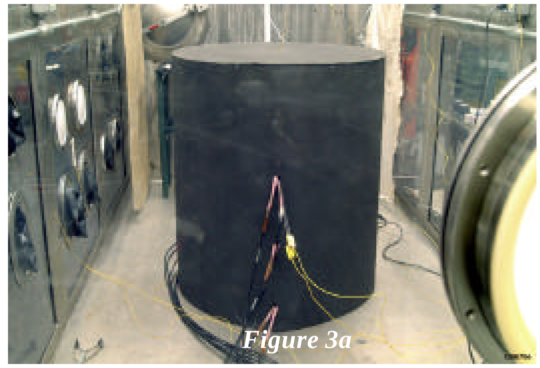

Figure 3a

Figure 3b

The principal concern from a containment integrity standpoint was to determine if the thermal loads and gradients could cause the polycarbonate windows to distort sufficiently to unseat their clamped–and–gasketed seal to the gloverbox frame. The glovebox metal frame is rigid and does not expand significantly at these temperatures. The test was run at positive pressure so the response of the pressure control system could be monitored. Serious leaks would show up as continuous purge, and even small leaks could be inferred from changes in the exhaust cycle intervals during the heatup transient.

The last aspect of the test design was to place movable welding cloth curtains between the furnace and closest two windows such that the incremental effects of radiant heating could be studied during the test.

Results

Once the simulated furnace was installed in the enclosure and checked out, a series of low to medium power runs were performed to establish baseline temperatures and response times. A final test at power levels increasing to maximum of 21kW over 4.5 hours is presented in *Figure 4*, and is the primary basis for the subsequent discussion.

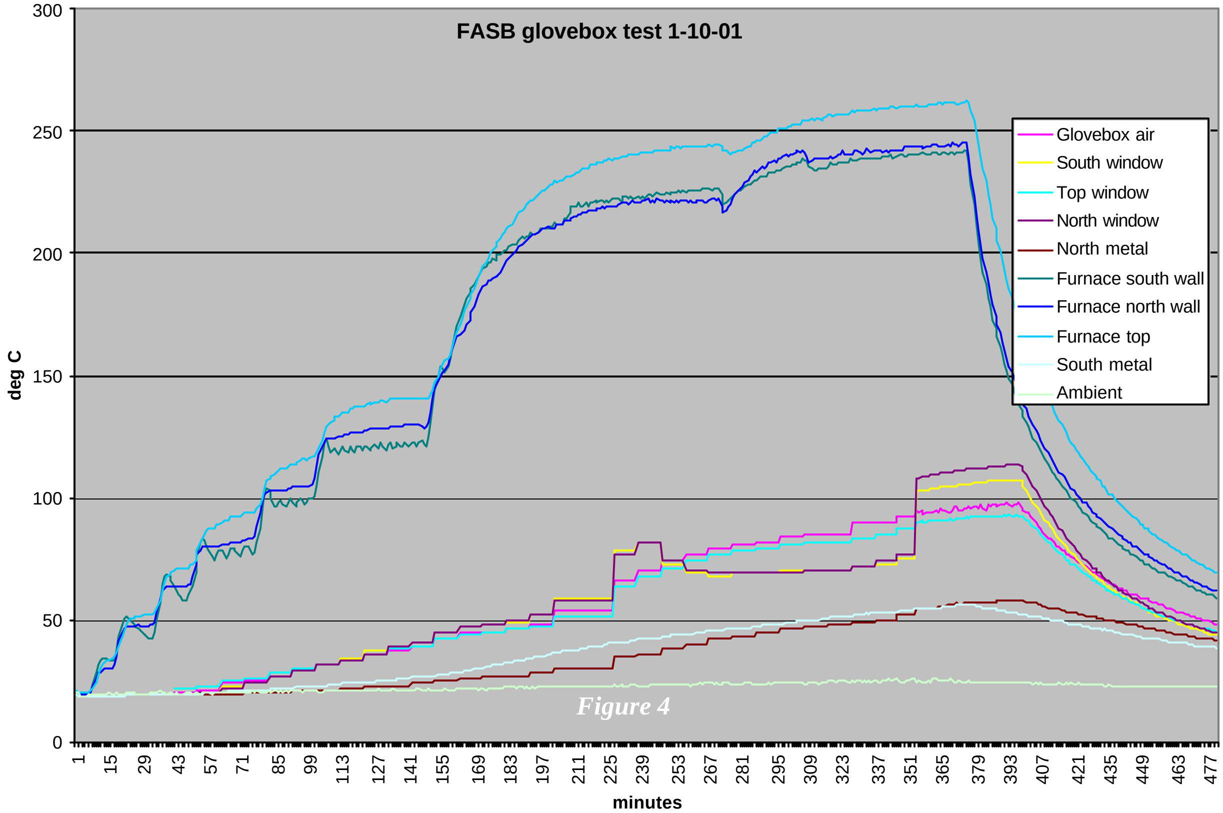

Figure 4

The windows and their effects on containment integrity as they heated and distorted were the principle focus during the test itself. Heating in the box was non-uniform, with both the highest atmosphere temperatures and the majority of the infrared loading at the windows nearest the furnace. These windows bowed in and out up to 1.75 inches at their center during the test, but showed no sign of leakage or damage. They returned to their original flat shape on cooldown, again without apparent damage. Some windows bowed in and some bowed out—indicating that the bow direction was not just the slight positive pressure distorting a softening plastic, but caused by an initial distortion or stress before heating occurred. Temperature gradients caused by the 3/8-inch window measured up to 31° C (56°F), and the windows generally ran hotter than glovebox frame that holds them in place. The coefficient of thermal expansion for the polycarbonate is also much larger than for the stainless steel frame. The initial temperature of windows and frame was 26°C. The temperature of the windows was 113°C and the frame as 58°C. The difference in thermal expansion between windows and frame cause the windows to bow in a rigid mounting even without pressure loads. The effects of the gasketed mounting and residual edge movements from the clamping bars are difficult to assess but were adequate to prevent leaking.

Peak atmosphere and window temperatures (see *Table 1*) were higher than predicted, which is not surprising given how non-uniform they were. The instrumentation was insufficient in cold areas of the box to calculate an average temperature for the box to compare to the models.

Maximum Temperatures:

• Glovebox air	97°C	207°F
• South window	107°C	225°F
• Top window	93°C	199°F
• North window	113°C	235°F
• South glovebox wall	56°C	133°F
• North glovebox wall	58°C	136°F
• Furnace shell south	242°C	468°F
• Furnace shell north	245°C	473°F
• Furnace shell top	262°C	504°F
• Ambient air	26°C	79°F
• Pipe Section	582°C	1080°F

Table 1

The effect of the curtains was very noticeable, especially when they were opened (time = 355 minutes in Figure 3) after having been closed for an hour or more. The window temperatures rose up to an additional 30°C in a few minutes. Even without the curtains, temperatures were within the allowable, but the curtains should lengthen the operational life of gasket and glove materials by significantly reducing peak temperature.

The pressure control system responded as expected to the transient and never exceeded 50% utilization on the exhaust cycle.

Conclusions

The test successfully demonstrated that the large glovebox would maintain its confinement integrity during the anticipated furnace runs, even in the absence of active cooling. Atmosphere and component temperatures were high but within allowable limits. They were sufficiently high in the peak areas that it was decided to add active cooling anyway. This will prolong glove and gasket lifetimes, and speed cooling of the furnace to a safe opening temperature. Curtains should be added as a precautionary measure.

The pressure control system managed the transient without problem and even served as a primitive passive leak detection system. It turned out to need significant supply capacity upgrades to keep up with the startup transient of the 10kW Mitsubishi air conditioner we installed, but it managed the furnace transient well.

Post Script

The enclosure went operational with the development furnace and air conditioner installed in November 2001. The furnace has now completed more than a dozen runs without enclosure or containment problems.

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